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(56) Documents cited
GB A 2096812 GB A 2069211 GB 1483192
GB A 2084370 GB 1536904 WO A1 8400073

(58) Field of search
G4V

(54) **Coin detection**

(57) Method and apparatus for detecting and identifying coins or other similar bodies (16) provides for application (at 12) virtually simultaneously of different frequencies electromagnetic excitation, then comparison of sensed results of coin or similar body presence with known data for standard coins or similar bodies. A single suitably shaped pulse can be used for excitation.

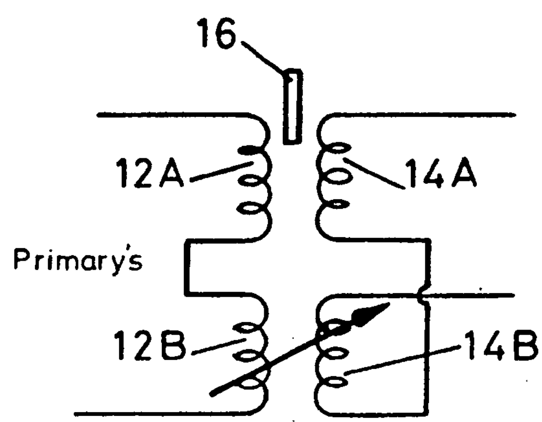

FIG. 1

GB 2 160 689 A

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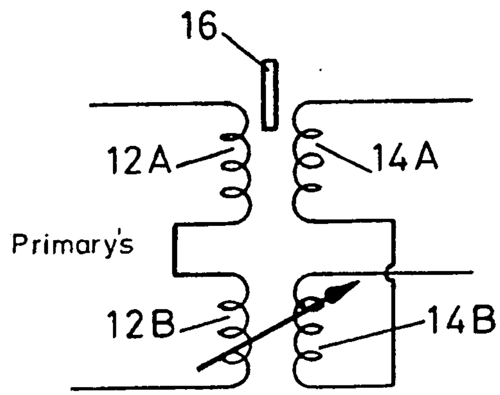


FIG. 1

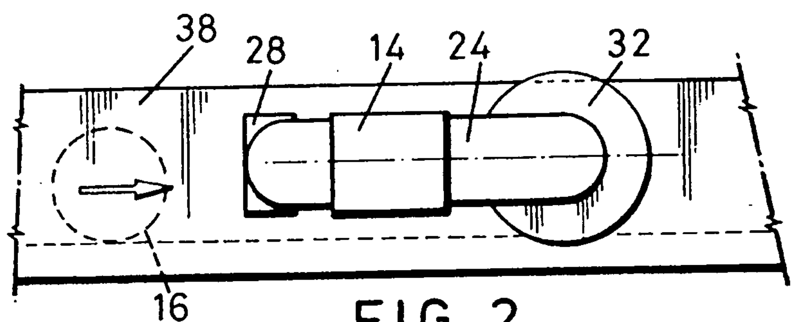


FIG. 2

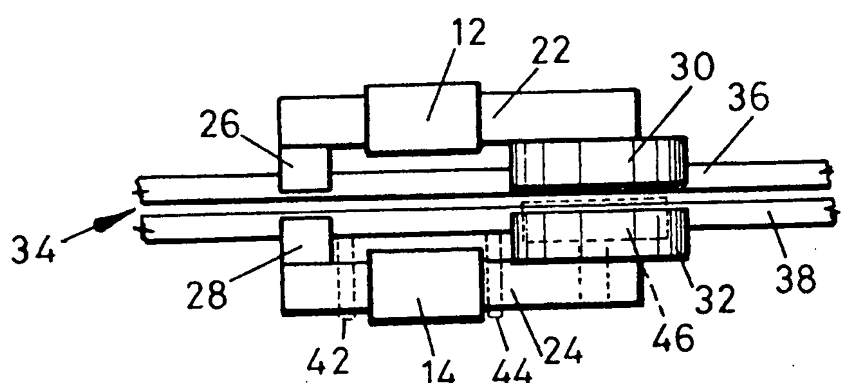


FIG. 3

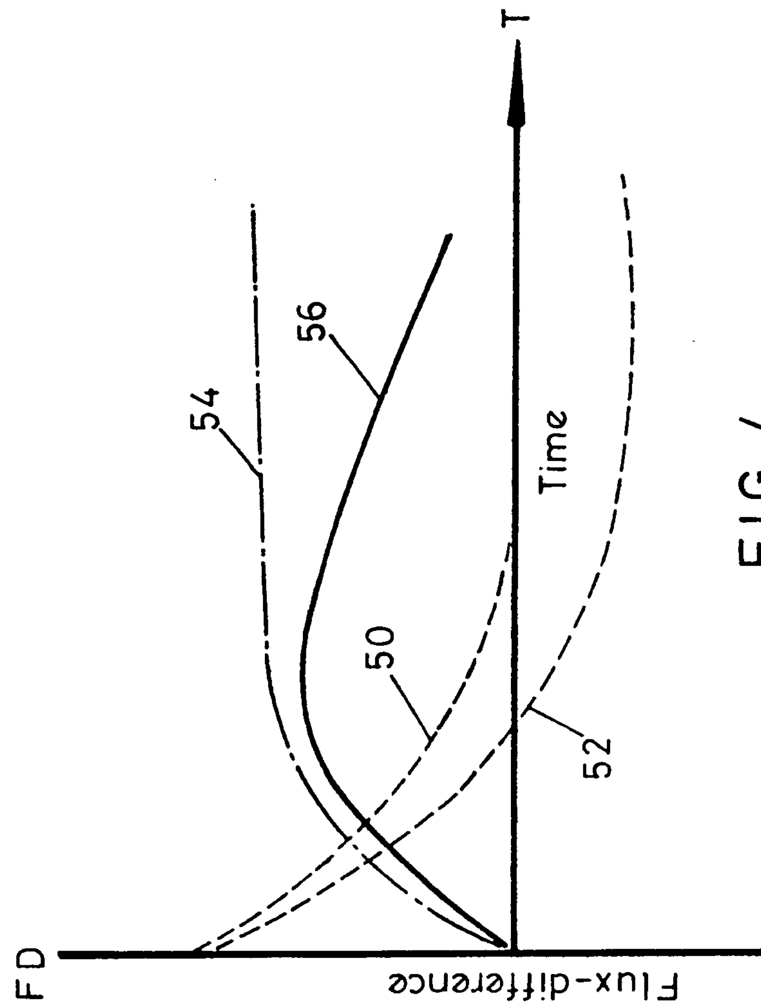


FIG. 4

2160689

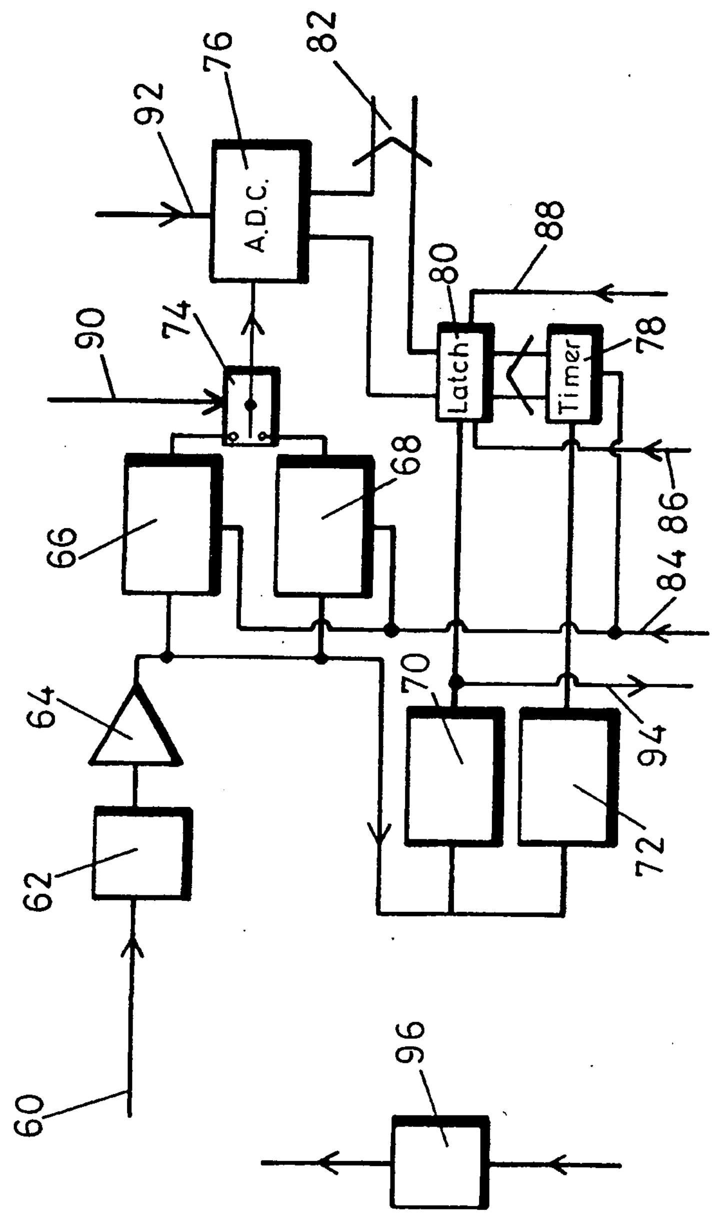
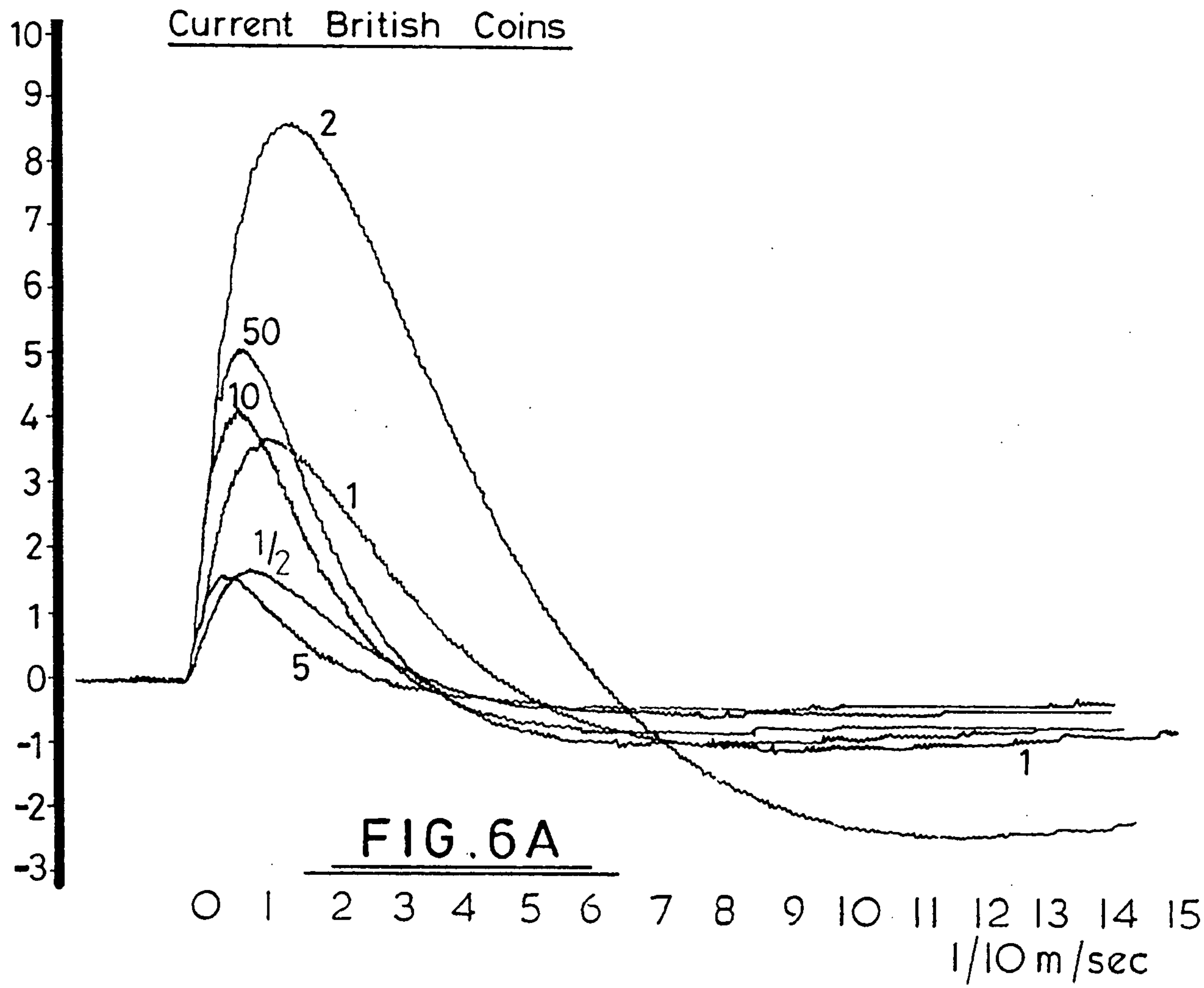


FIG. 5



Current British Coins
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
2
50
10
1
1/2
5
1
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1/10 m/sec

FIG.6A

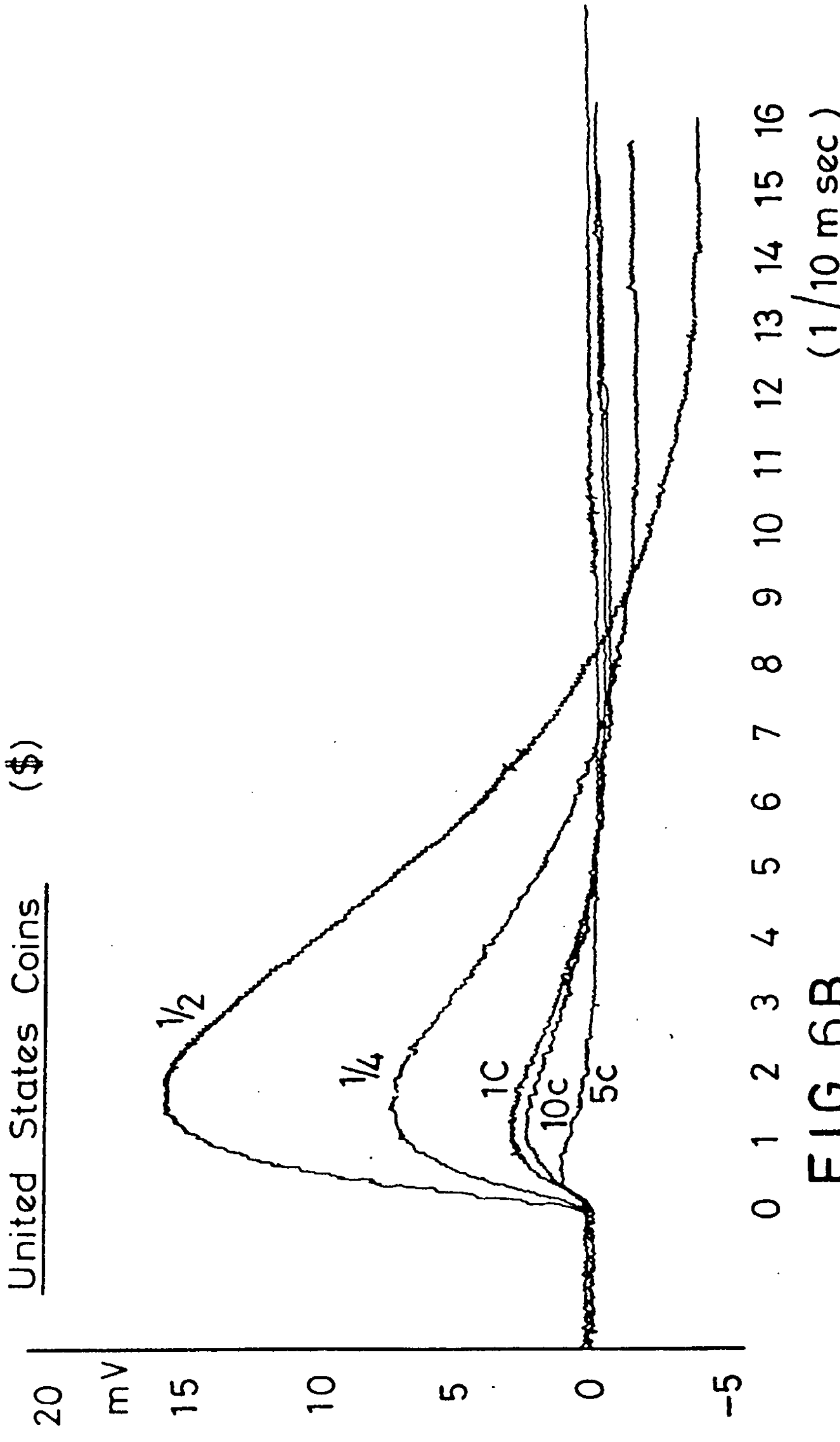

United States Coins
($)
20
mV
15
10
5
0
-5
1/2
1/4
1C
10c
5c
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
(1/10 m sec)

FIG.6B

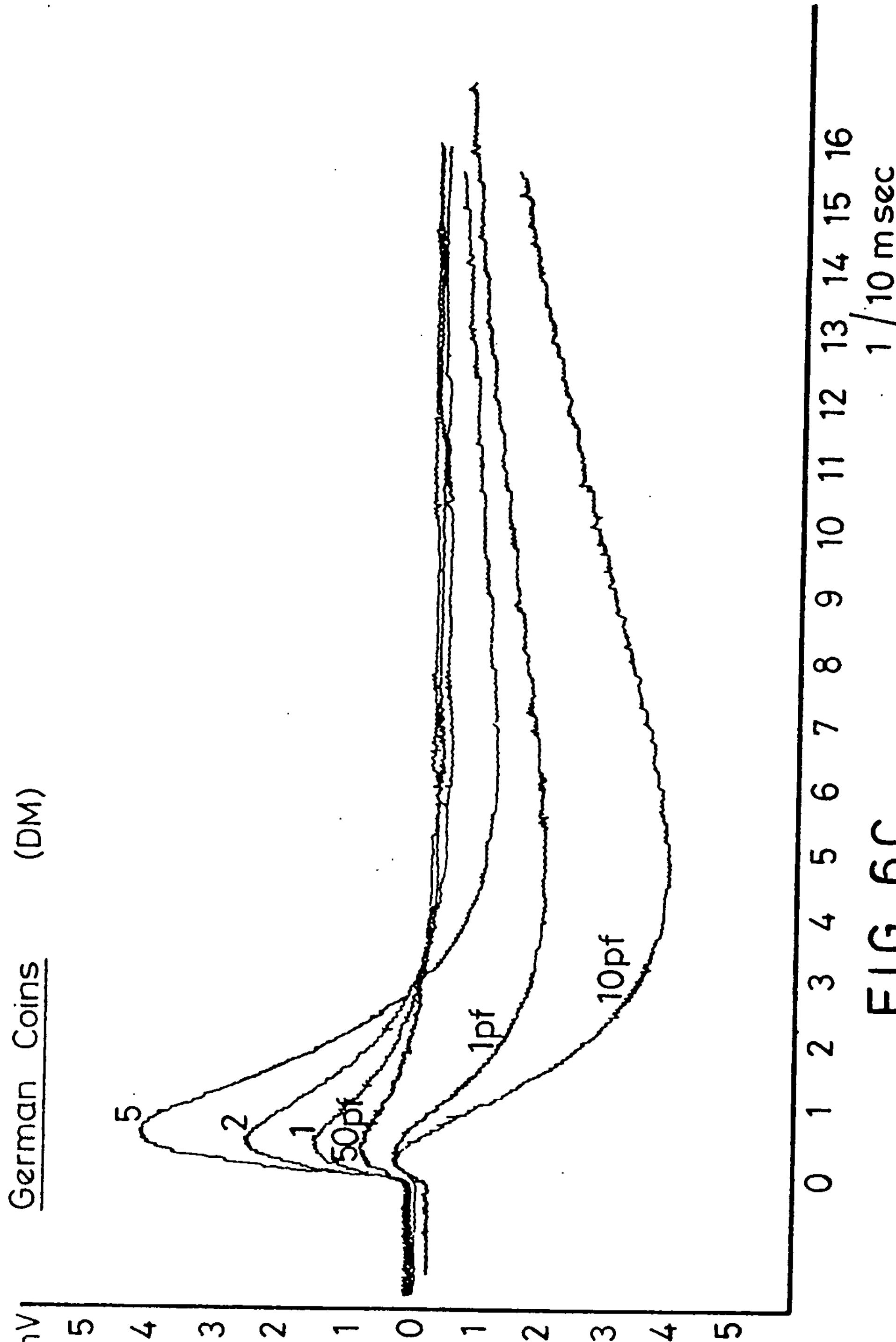

German Coins (DM)
mV
5 4 3 2 1 0 1 2 3 4 5
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
1/10 msec
5
2
1
50pf
1pf
10pf

FIG. 6C

2160639

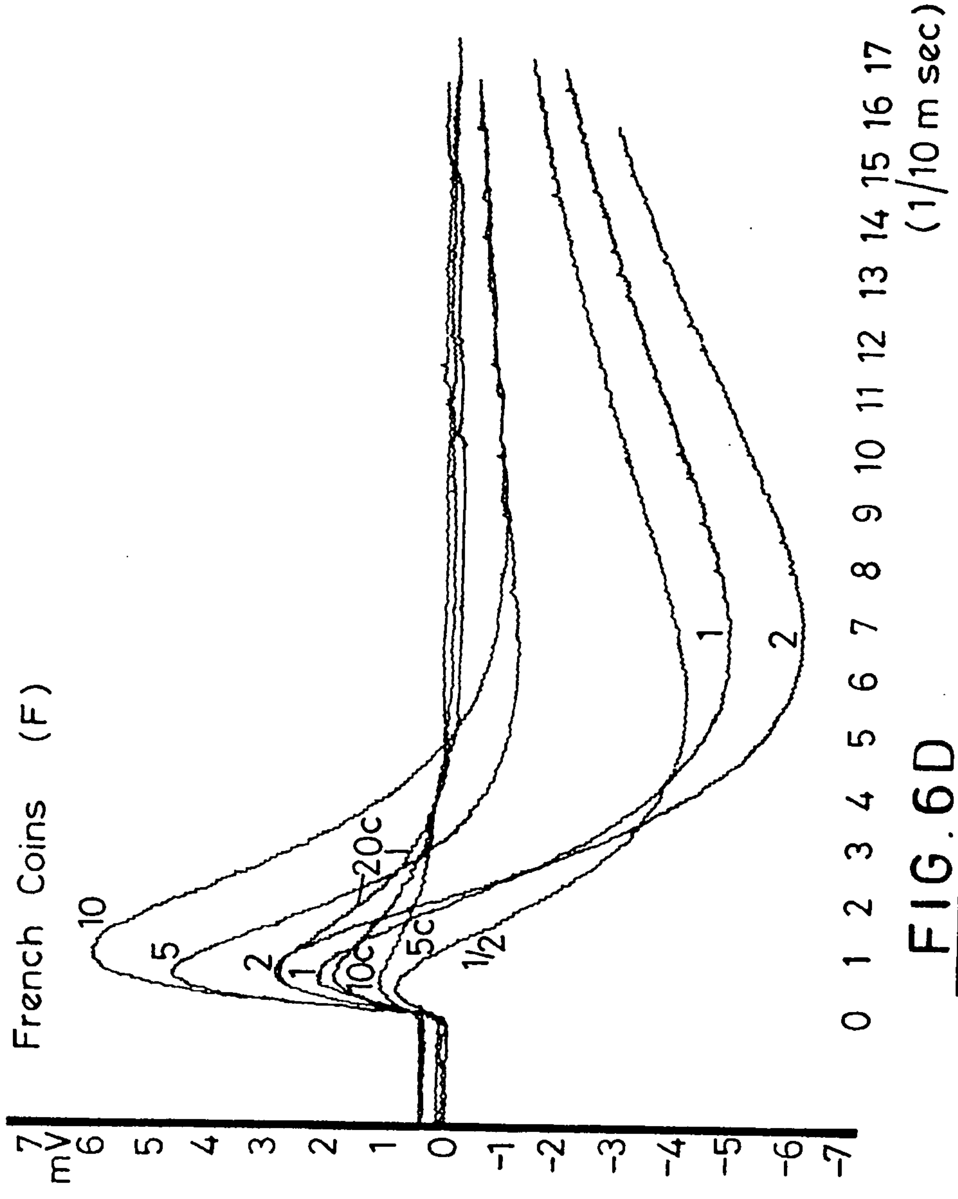


FIG. 6D

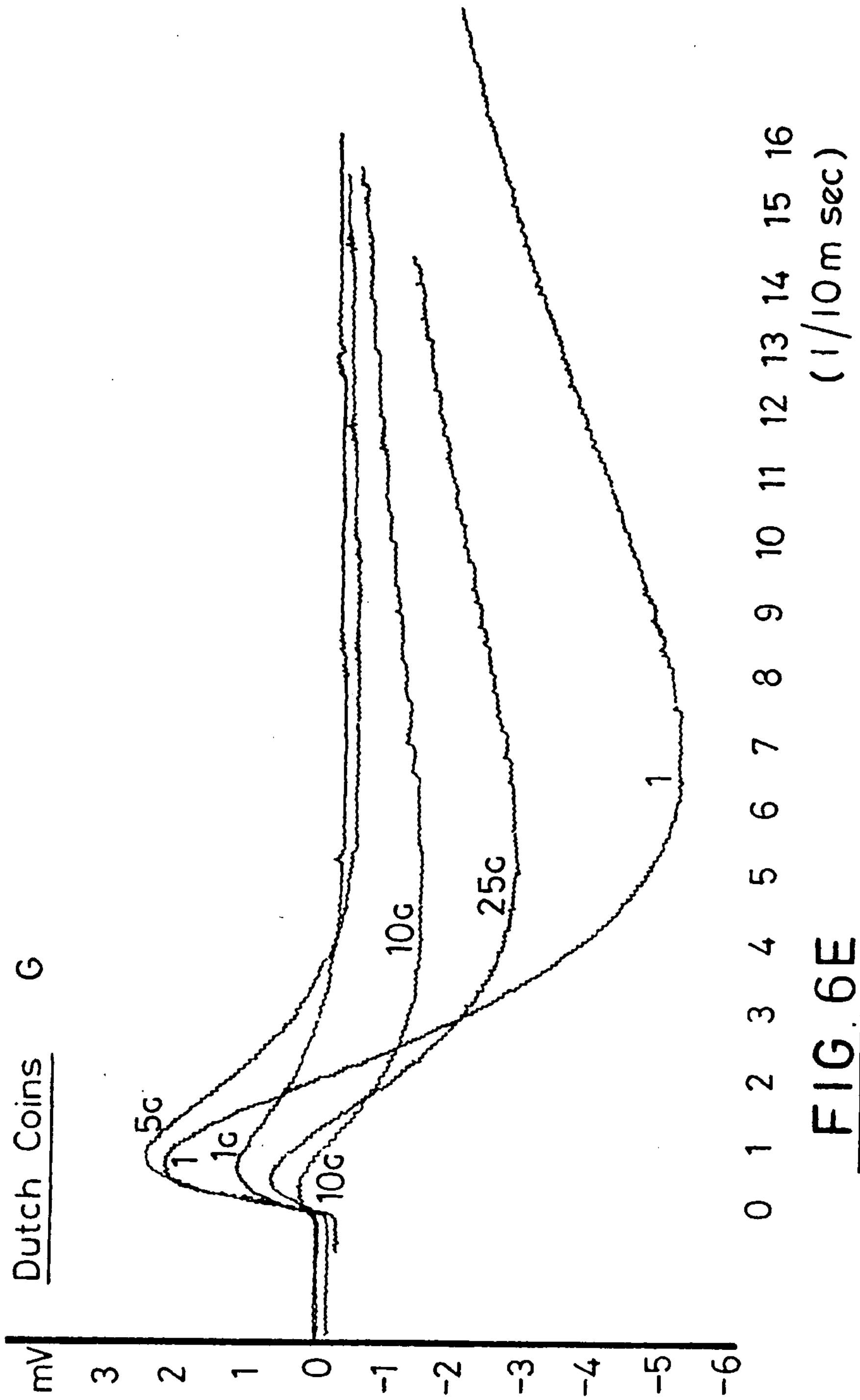

Dutch Coins G
mV
3
2
1
0
-1
-2
-3
-4
-5
-6
5c
1
1c
10G
10G
25c
1
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
(1/10m sec)

FIG 6E

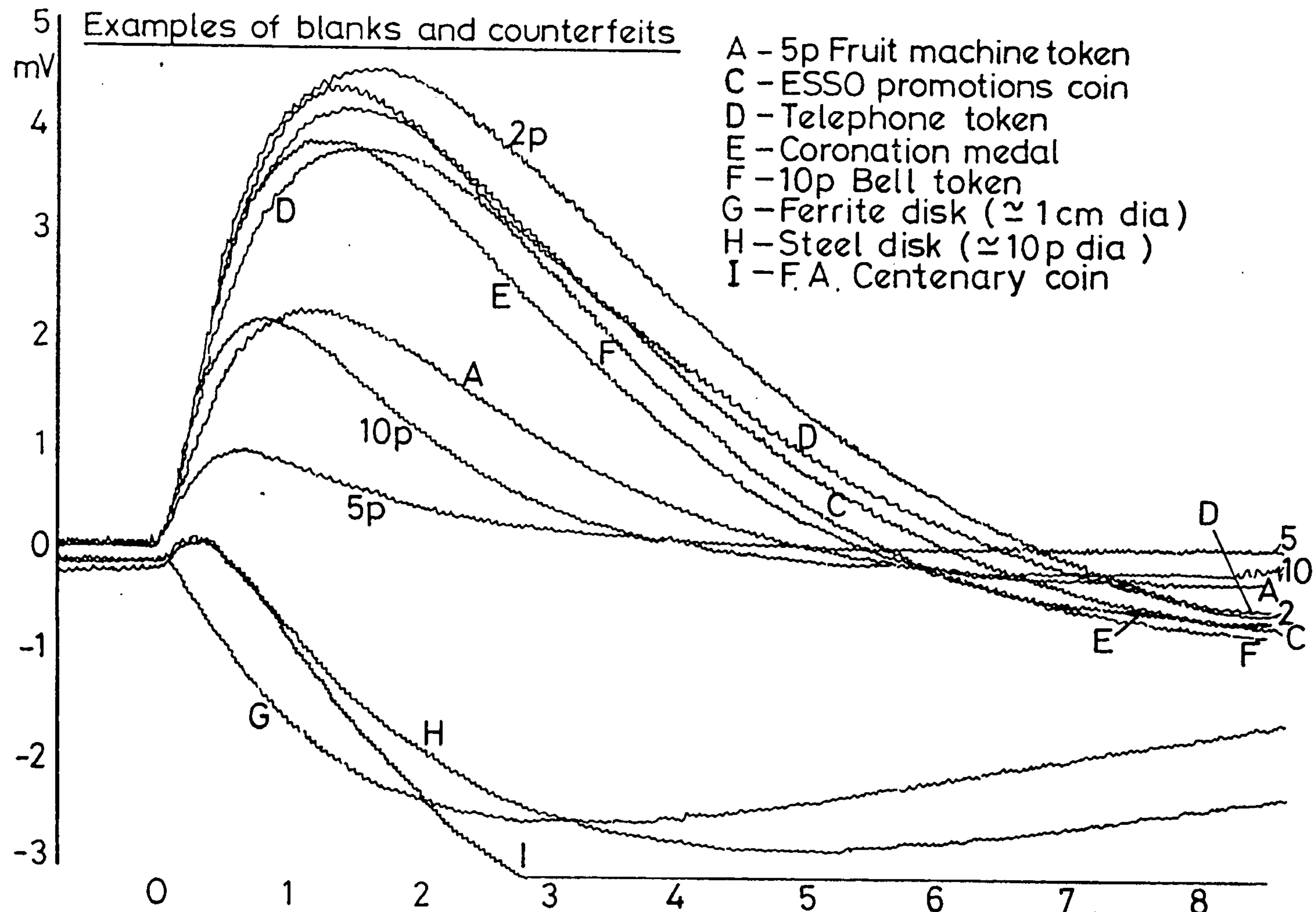

Examples of blanks and counterfeits
A – 5p Fruit machine token
C – ESSO promotions coin
D – Telephone token
E – Coronation medal
F – 10p Bell token
G – Ferrite disk (≃ 1 cm dia)
H – Steel disk (≃ 10p dia)
I – F.A. Centenary coin
5
mV
4
3
2
1
0
-1
-2
-3
0
1
2
3
4
5
6
7
8
1/10 m sec
2p
D
E
F
A
10p
5p
C
10
2
G
H
I

FIG. 6F

SPECIFICATION

Coin detection

The invention relates to coin, token etc detection, particularly, but not necessarily exclusively, in the context of so-called coin-freed systems.

In relation to coins, detection systems are known that utilise electromagnetic excitation of a region containing the coin and through which the coin passes. The presence of a coin will produce a detectable effect for suitable excitation, which effect is generally due to the electro-magnetic induction or absence thereof in the coin, i.e. almost regardless of the material of the coin, token or whatever body. For an electrically conductive and/or magnetically permeable material, there will be positive induced effects within the material, and we are particularly interested in an effect which we shall call skin-conduction that basically corresponds to skin-effect eddy currents.

It is the case that such skin-conduction must have arisen in relation to known coin detecting systems, but hitherto limited to energisation/sensing at one (or each) of several stations to indicate presence/absence and/or size (usually in terms of diameter) and often allied with other system facilities, such as highly accurate weight determination and/or size categorisation and routing, in order to complete the validation of a coin as being of a particular denomination of value.

This invention is based on our belief that, for materials (usually metal alloys) presently used and likely to be used for coins, the nature of the skin-conduction effect should be capable of excitation and detection at a single station in a manner that permits of complete or at least a greater degree of identification, and thus validation, of coins within a particular currency, with an acceptable rejection of foreign coins or other fraudulent bodies. It is thus an object of this invention to provide such a method and system, preferably capable of implementation with costs and/or performance advantages over presently available systems, at least in relation to controlling coin-freed mechanisms.

According to this invention use is made of the outcome of our investigations of sensing the results of different frequencies of electromagnetic excitation of a region of or for detection, and comparing the sensed results with known data.

Technically, of course, it is feasible to apply a succession or sweep of frequencies and to sense results in a time-spaced, synchronised or otherwise related manner.

The fact that such an implementation would require significant time and/or substantial physical extent of the excitation/sensing system, or stopping the coin or other body for an appreciable time, is a disadvantage in terms of system response that we seek to overcome in preferred embodiments of the invention.

Accordingly, in one aspect, the invention proposes a method and/or apparatus of or for a system wherein a coin or other body can be subjected to a number of different frequencies virtually simultaneously, which can be achieved, we find, using what amounts to a single cycle, half cycle or pulse of a repetitive or cyclic energisation signal, or, indeed, a simple step signal.

It is, of course, well-known from Fourrier analysis that a square-wave, i.e. a steep-sided substantially flat-peak waveform, can be considered as comprising a fundamental frequency sine-wave plus other sine waves at odd-numbered harmonics of the fundamental in ascertainable proportions. In analogous ways, other waveforms, such as saw-tooth and step functions, can be shown to comprise harmonically related frequency components.

Such multi-frequency content signals applied to primary winding(s) of a sensor are found to yield in secondary winding(s) of that sensor frequency components that are dependent on the coin then affecting the sensor and in a manner leading to production of an identifier waveform at least by integration of the sensor output.

It is convenient at this stage to continue description of the invention by reference to exemplary practical implementation to which the accompanying drawings refer. In those drawings,

Figure 1 is a circuit diagram for a balanced sensor;

Figures 2 and 3 are side and plan views of a purpose-designed sensor;

Figure 4 is a graph type diagram of flux-difference against time for response of a balanced sensor;

Figure 5 is a block diagram of interfacting circuitry for processing information by computer; and

Figures 6A to 6E show examples of preliminary results for British, U.S., German, French and Dutch coins, and *Figure 6F* shows some non-coin objects.

Referring first to Figs. 1 to 4, a balanced sensor 10 comprises primary windings 12 and secondary windings 14 between which a coin 16 can pass for sensing purposes. The primary and secondary windings 12 and 14 are shown in Fig. 1 as two pairs of windings 12A, 12B and 14A, 14B in a configuration such that outputs from the pair of secondary windings 14A, 14B tend to cancel each other.

The windings 12, 14 are preferably installed on suitably shaped cores of ferrite material having high magnetic permeability and low electrical conductivity. The result is a low reluctance magnetic circuit with a concentrated magnetic field and little or no eddy current losses in skin-conduction effects in the cores themselves. Figs. 2 and 3 show one

configuration where first ferrite body parts 22, 24 carry sensor coils 12, 14 at medial positions between their ends at one pair of which are pole pieces 26, 28 to act in triggering operation and at the other pair of which are pole pieces 30, 32 to act for sensing or measuring purposes. It will be noted that the sensing pole pieces 30, 32 are shown relatively large, so as to encompass admissible sizes of coins 16 entrant via a coin guideway 34 shown with sides 36, 38 to hold the coins upright and conveniently associated with affording suitable mounting of the coils and pole pieces.

Adjustment is considered advisable in order to be able to balance the coils and obtain a true null output from the sensor when no coin is present, see arrow 40 for coils 12B, 14B in Fig. 1. In Fig. 2, that may be achieved by a suitable spacer bolt, see dashed at 42, 44 for ferrite body 24 in Fig. 2, preferably of non-magnetic material e.g. nylon; or by a screw-adjusting ferrite slug, see dashed at 46 for the pole piece 32.

At the measuring pole pieces 30, 32, of course, design of the sensor will take best account of having the smallest area of magnetic field and width of air gap consistent with exceeding the size of the maximum admissible coin and allowing the thickest coin to pass without undue wear problems. At the preferred triggering pole-pieces 26, 28 the main consideration is to get maximum concentration of magnetic field so as to get a large triggering signal, further preferably using the same detect circuitry as for measurement sensing and processing, hence the showing of much smaller pole pieces.

Using a balanced sensor having a null output for no-coin-present, and a step-type of energisation of the primary coils for detection/measuring purposes, the first result for coin-present is that the secondary coils output will rise correspondingly, though not quite so steeply as the applied voltage due to an inductance-resistance time constant inherent in the resistance of the primary winding and of the driving stage being effectively in series with the winding inductance. Such applied and detected steps are, of course, associated with a corresponding step in the magnetic field. The initial high-fequency contents of the step waveform produce skin-effect eddy currents in a coin and thus a shielding effect relative to penetration of the coin by the magnetic field. The result is a reduced effective coupling between the pole pieces 30, 32 and thus the coils, and therefore a relatively high imbalance between the coils, which is actually directly dependant on the area of the coin. Later in the step waveform, the effective frequencies reduce in rate, the skin-effect eddy currents in the coin reduce, and there is increased penetration of the coin by the magnetic field, which tends to restore balance on the sensor-windings. At least the time constant of this action depends on the "skin-depth" parameters of the coin in relation to induced eddy currents and the thickness of the coin.

Such imbalance is indicated by dashed lines 50 and 52 in Fig. 4 for non-ferromagnetic and ferromagnetic (e.g. containing nickel) coins, respectively. Fig. 4 also shows an idealised integration of such imbalancing at the chain-dashed line 54, and a corresponding output 56 from a practical integrating network, i.e. having a time constant.

We find that waveforms 56 are, in fact, sufficiently characteristic for coins of a particular series or currency to enable ready identification, and that good discrimination is also achievable against foreign objects, whether coins or otherwise, see Figs. 6A to 6F.

The most convenient way to store standard waveform information and to compare input waveforms from the sensor is, these days, by using a digital electronic computer, and it is technically feasible to use analogue-to-digital conversion techniques and circuitry in order to produce input data for such a computer, and to do so for the entire input waveform so far as relevant, whether using fast analogue-to-digital converters having of the order of 10,000 conversion per second, say to an 8-bit resolution or equivalent, or employing analogue sample and hold circuits to enable use of lower rate digitisation circuitry.

Alternative digital treatment is to select certain parameters of the sensor output and to digitise only those, so long as those parameters are coin-characteristic. Such parameters may include maximum amplitude excursions and times to and between same. That obviously reduces storage and data generation requirements.

One implementation of the latter alternative is indicated in the block circuit diagram of Fig. 5. There, coin detection waveform from the sensor at line 60 are conveniently voltage-adjusted or "pedestalled" at 62 and amplified at 64 in order to always be within a convenient 0 to 5 volts. That suitably conditioned signal is then shown going to four circuits, namely sample and hold circuits 66, 68 for positive and negative peak sampling and holding, a peak-instant detector 70 and a preset threshold detector 72. A selection circuit 74 is shown relative to outputs from the sample-and-hold circuits 66, 68 and feeding same to an analogue-to-digital converter 76 where the circuits 66, 68 are of analogue tyre. The circuits 70, 72 are shown feeding timer (78) and latch (70) circuits operative in establishing time-to-positive peak and interval then to threshold and/or between thresholds. The analogue-to-digital converter and latch are connected to a data bus 82 to a computer which will conveniently provide various timing and control signals including reset on line 84

for the sample-and-hold circuits 66 and 68, latch store and read controls on lines 86 and 88, peak selection on line 90, and analogue-to-digital converter enable on line 92.

In addition, Fig. 5 shows a coin-present output 94 from the positive-peak detector 70, which is actually for response to output from coin traversal of the triggering pole pieces 26 and 28, in respect of which it is convenient for a driver stage 96 supplying the sensor primary winding 12 to be effective for supplying a pulse stream until a coin is detected via line 94 and then to apply the step signal at a time appropriate to the coin being between the measuring poles 30, 32.

There is obvious advantage to be gained from maximum precision in assuring an accurately known time internal from triggering to coin-present between the measuring poles 30, 32. One way to do so without requiring very close adjoining of the triggering and measuring poles is by careful design of the coin feed track.

In that connection, one favoured approach is for the track to rely largely on gravity-action on the coin between those poles. That can be achieved if the track has a first section that removes all or nearly all of any vertical component of coin speed, say some substantially horizontal run, then effectively virtually to stop the coin for subsequent acceleration by gravity, say by bouncing the coins off to an angled run through the sensor. In addition, such sudden acceleration can usefully serve in separating two coins closely following each other. Sides of the coin track are conveniently very smooth and of electromagnetically inert material, such as perspex or suitable material with an anti-friction coating. Such sides further facilitate provision of a non-return gate between the triggering and measuring poles, a valid-coin gate and a reject-coin gate (preferably normally in reject mode). Such gates can be by controlled projection across the preferred sides of the coin track.

CLAIMS

1. Method of detecting coins or other similar bodies wherein a coin or similar body is subjected virtually simultaneously to a number of different frequencies of electromagnetic excitation, and results thereof detected and compared with known data for particular coins or similar bodies.

2. Apparatus for implementing the method of claim 1, comprising a test station to or through which will pass a coin or similar body, means for applying multiple frequencies of electromagnetic excitation substantially simultaneously at said test station, means for sensing results of presence of said coin or similar body, and means for comparing said results with known data for particular coins or similar bodies.

3. Apparatus according to claim 4, comprising means for temporarily holding said coin or similar body in the test station.

4. Apparatus according to claim 2 or claim 3, wherein the test station is at an intermediate position in a track traversed by said coin or similar body under gravity.

5. Method or apparatus according to any preceding claim, wherein the excitation is by way of a particular shaped pulse of multiple frequency content.

6. Method or apparatus according to any preceding claim, wherein said pulse is of substantially square or stepped waveform.

7. Method of identifying coins or other similar bodies substantially as herein described with reference to the accompanying drawings.

8. Apparatus for identifying coins or other similar bodies arranged and adapted to operate substantially as herein described with reference to and as shown in the accompanying drawings.

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